Multilayer, Designer Materials

Nanoengineering creates incredibly strong microstructured materials

Designer materials—once only a dream—are now close to reality. With the nanoengineering process developed at LLNL, scientists can specify materials properties and then fabricate the materials to meet those specifications. We are now able to control the structure of materials to an extent never before possible.

How did we do it?

The design of solid-state devices with multilayered materials brought thin-film technology to the marketplace. LLNL has achieved a scientific breakthrough by developing a nanoengineered multilayering process to produce new, microstructured materials. At the heart of this new process is the ability to control layering:We have synthesized samples with as many as 40,000 individual layers. Because we can control the composition and structure of these materials at the near-atomic level, we can control the uniformity of thickness and composition of the layers and produce thick films of high purity and structural quality.

In the laboratory, we have made flat samples that are 62.5 cm in diameter and 0.2 mm thick. We are preparing to use this process to produce cylindrical samples that are 1 mm thick.

APPLICATIONS

- *Fabricated metals that are very hard, very smooth, and nearly frictionless*
- *Improved performance integrated circuits*
- *Materials for motor and engine design*
- *Materials viable at both high and low temperatures*

Nanoengineering increases tensile strength

To illustrate the strength of these designer materials, we created a multilayered material composed of individual copper and Monel (an alloy composed of copper and nickel) layers. We then predicted the tensile strength of this material based on the characteristics of the individual metals. The actual tensile strength of the designer material was six times this bulk value! This designer material approaches 75% of the theoretical strength of metals.

Mechanical properties of thick, multilayer materials synthesized from copper, 304 stainless steel, zirconium, platinum, and chromium.

Material	Period (nm)	Hardness (measured) (GPa)	Strength (ksi)	Strength enhancement[a]
Pt/Cr	3.5	11.5	556[b]	~10
304 SS/Zr	2.72	9.3	450[b]	~8
Cu/Zr	40.0	2.7	152[c]	~5
Cu/304 SS	2.0	5.2	243[c]	~4
Cu/Monel	2.0	4.4	210[c]	~3.5

[a] Measured strength divided by that estimated from volume average of properties of individual layers.
[b] Estimated from hardness measurements.
[c] Measured in standard tensile tests ($\varepsilon = 5 \times 10^{-5}\ s^{-1}$)

More efficient, longer lasting equipment

LLNL's team of scientists has expanded the boundaries of materials science. As a result, we can fabricate metals that are very hard, very smooth, and nearly frictionless. This achievement has many applications. For example, integrated circuits can now be produced with enhanced properties, and equipment manufactured with these materials can have a longer life. Motor and engine design is no longer bound by the limits imposed by existing materials as new materials can be designed that will be viable at high or low temperature. Automobile engines would not need cooling systems if the engines were fabricated from designer materials; fuel efficiency and range would also be extended.

Designer materials are not a vague dream for the distant future. In some applications, LLNL's multilayer technology could yield commercial products in as few as three years.

Availability: The technology is available now. We seek industrial and government partners interested in developing that technology for commercial applications.

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